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Coal Resource Occurrence and Coal Development Potential Maps of the Northeast Quarter of the Mt. Pennell 15-Minute Quadrangle, Garfield County, Utah

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Text to Accompany
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1980
COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT
POTENTIAL MAPS OF THE
NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE,
GARFIELD COUNTY, UTAH
[Report includes 13 plates]

Prepared for
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

By
DAMES & MOORE
SALT LAKE CITY, UTAH

This report has not been edited
for conformity with U.S. Geological
Survey editorial standards or
stratigraphic nomenclature.

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) Maps of the Northeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah. These maps and report were compiled to support the land planning work of the Bureau of Land Management and to provide a systematic coal resource inventory of coal lands in the Henry Mountains Known Recoverable Coal Resource Areas (KRCRA's), Utah. Consequently, only those geologic features relevant to coal occurrences are described herein.

This investigation was undertaken by Dames & Moore, Salt Lake City, Utah at the request of the U.S. Geological Survey under contract number 14-08-0001-17489. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through June, 1979, was used as the data base for this study. Neither drilling nor field mapping was performed; nor were any confidential data used.

Location

The Northeast Quarter of the Mt. Pennell 15-minute quadrangle is located in central Garfield County, Utah in the southern part of the Henry Mountains coal field. The area is approximately 29 miles (46.7 km) south of Hanksville and 15

miles (24 km) west of Highway 276. Bullfrog Basin on Lake Powell is roughly 30 miles (48 km) to the south.

Accessibility

One jeep trail winds part way up the east side of Mt. Pennell to Straight Creek near the east side of the map area. Otherwise, access is limited to horse or foot travel. Winter access is restricted by snow and winds.

Physiography

Mt. Pennell, in the northeast central part of the map area, is the dominant physiographic feature in the Northeast Quarter of the Mt. Pennell 15-minute quadrangle. It is a symmetric dome with a central intrusive stock and numerous peripheral sills and dikes. Deformed sedimentary rocks on the otherwise moderate smooth slopes of the mountain have been cut by steep-walled narrow drainage channels. Slump and landslide debris cover many of the slopes.

Sedimentary rocks around the foot of Mt. Pennell, in the southern and western map areas, have been weathered to badlands. Erosion, where stopped by resistant sandstone, has locally produced small, gently sloping mesas. Continued erosion through sandstone into shale along drainages originating on Mt. Pennell has resulted in a radial pattern of rugged badlands and canyons.

Elevations range from a maximum of 11,371 ft (3,468 m) atop Mt. Pennell to a low of 5,120 ft (1,561 m) along Bullfrog

Creek in the southwest corner of the map area. Total relief is 6,251 ft (1,905 m).

Except for drainages on the north and east flanks of Mt. Pennell, runoff is directly to Lake Powell via Bullfrog Creek.

Water quality and stream flow reflect seasonal climatic changes. Most surface water is saline due to a high evaporation rate during the summer. Streams at elevations below 8,800 feet (2,682 m) commonly dry up in the late summer months.

Climate and Vegetation

The quadrangle's climate ranges from semi-arid to arid. Average annual precipitation is 20 to 25 inches (51 to 64 cm) on Mt. Pennell; rainfall and snow accumulate roughly 12 inches (30 cm) in the tablelands to the west and south of Mt. Pennell. Annual precipitation varies from year to year, however, due to the erratic nature of desert rainfall. Drought periods of three or more years are common.

Temperatures range from over 100°F (38°C) in the late summer months to below 0°F (-18°C) during the winter. The yearly average for the region is 56°F (13°C) (U.S. Bureau of Land Management, 1978). As a rule, temperatures drop with increasing elevation.

Winds usually blow from the west and southwest. Higher seasonal velocities occur during the spring and early summer.

Principal types of vegetation in the area include grass, sagebrush, pinon, juniper, salt brush and greasewood (U.S. Bureau of Land Management, 1978).

Land Status

The quadrangle encompasses the extreme eastern edge of the Henry Mountains Known Recoverable Coal Resource Area. Coal lands are located principally in the northwest corner of the Northeast Quarter of the Mt. Pennell 15-minute quadrangle. The Federal government owns most coal rights, as shown on plate 2 of the Coal Resource Occurrence maps. Roughly 96 percent of the land area is under Federal control. The state of Utah holds the remaining 13.9 percent of the acreage. No Federal coal leases, prospecting permits or licenses are outstanding in the map area.

GENERAL GEOLOGY

Previous Work

John Wesley Powell, one of the first explorers of the region, named the Henry Mountains in 1869 and made some of the first geologic comments (Gilbert, 1877) on the area. G. K. Gilbert (Gilbert, 1877) studied the Henry Mountains during 1875 and 1876. His report is considered one of the classics of geological literature. Gregory and Moore (1931) and later Smith and others (1963) and Davidson (1967) reported on parts of the Waterpocket Fold in the region.

The first investigation of coal resources in the Henry Mountains was undertaken by C. B. Hunt, who commenced work on the area in 1935, completed field studies in 1939 and published the results in 1953 as U.S. Geological Survey Professional Paper 228. More recently, coal studies were completed by Doelling (1972) of the Utah Geological and Mineralogical Survey and Law (1977) of the U.S. Geological Survey. The results of these later investigations provided most of the data used in this coal resource evaluation. Additional publications which describe geologic features in the region are included in the bibliography.

Stratigraphy

The Jurassic Entrada, Summerville and Morrison Formations crop out in the northeast corner of the map area in the vicinity of Black Canyon.

The Morrison Formation also appears as the innermost of a series of strata domed and concentrically surrounding the Mt. Pennell intrusive stock. Overlying the Morrison Formation, farther from the stock, are the Dakota Sandstone, Tununk Shale, Ferron Sandstone, Blue Gate Shale, Emery Sandstone and Masuk Shale members of the Mancos Shale, all of Cretaceous age. A composite columnar section accompanied by lithologic description on CRO plate 3 illustrates the stratigraphic relationships of these units.

The Cretaceous Dakota Sandstone is the oldest known coal bearing unit in the quadrangle. It represents a westward transgressive littoral sequence and lies unconformably atop the varicolored Brushy Basin Shale member of the Jurassic Morrison Formation. The Dakota Sandstone consists of sandstone, conglomerate, carbonaceous shale and minor coal. The formation is an average 60 ft (18 m) thick in the map area (Hunt, Averitt, and Miller, 1953).

Cross bedded sandstones which form most of the Dakota Sandstone in this quadrangle may have been derived by reworking of underlying Morrison Formation strata in a fluvial environment (Hunt, Averitt, and Miller, 1953). Minor interbeds of yellowish-gray and carbonaceous shale reflect local marsh and lagoonal environments. A diagnostic bed of fossils containing Gryphaea, Exogyra and Inoceramus occurs either at the top of the formation or in the lowermost beds of the overlying Tununk Shale member (Hunt, Averitt, and Miller, 1953).

The Mancos Shale lies conformably over the Dakota Sandstone and fills the sedimentary basin in this part of the Henry Mountains. The lowermost, Tununk Shale member of the Mancos Shale is gradational and interfingering with the underlying Dakota Sandstone. It is about 570 ft (174 m) thick in the map area and represents a continuation of the first westward transgression of the Cretaceous sea in which the Dakota Sandstone was deposited (Peterson and Ryder, 1975).

The Tununk Shale member is a bluish-gray, fissile shale with numerous thin bentonitic horizons and subordinate, mostly thin-bedded, medium-grained sandstones. The member weathers to a bluish-gray, is generally poorly exposed and forms smooth broad valleys (Peterson and Ryder, 1975). The lowest few feet of the member everywhere contain abundant oysters (Hunt, Averitt, and Miller, 1953). Sandstones become more abundant toward the top of the member, where it is conformable and transitional with the overlying Ferron Sandstone member. The top of the Tununk Shale member is placed beneath the first thick-bedded or massive sandstone ledge in the transition zone (Peterson and Ryder, 1975). A regressive sequence, partially the result of deltaic progradation, occurs in the upper part of the Tununk Shale member (Hunt, Averitt, and Miller, 1953).

The Ferron Sandstone member, conformable upon the Tununk Shale member, is a regressive unit composed of littoral and coastal plain facies (Doelling, 1972). A lower, littoral unit is characterized by massive, gray to brown, fine- to coarse-grained

sandstone with thin shale interbeds. The upper portion of the member is a coastal plain deposit of interbedded sandstone, gray to brown shale and carbonaceous shale which is locally coal bearing (Hunt, Averitt, and Miller, 1953). Sandstones become lenticular and lighter in color upward in the section.

The Ferron Sandstone member is locally capped by a thin sandstone which probably represents a transgressing littoral deposit (Hunt, Averitt, and Miller, 1953). In this area the Ferron Sandstone member averages 168 ft (49 m) thick.

The Ferron Sandstone member is unconformably overlain by the Blue Gate Shale member. The contact between the Ferron Sandstone and the Blue Gate Shale members is generally sharp. Detailed correlation of sandstone beds in the Ferron Sandstone member suggests that 50 to 100 feet (15 to 30 m) or more of the top of the Ferron Sandstone have been removed by erosion at the unconformity in the region (Peterson and Ryder, 1975).

The Blue Gate Shale member of the Mancos Shale, like the Tununk Shale member, represents a transgressive sequence of marine deposition. It is composed of bluish-gray, finely laminated shale with thin beds of shaly sandstone and platy, calcareous sandstone in the upper one-third of the unit. The member weathers easily to form smooth valleys or broad benches. The lower part is concealed by alluvium in many places, but the upper part is generally well exposed in cliffs that are capped by Emery Sandstone (Peterson and Ryder, 1975). The average thickness of the Blue Gate Shale member in the Northeast Quarter

of the Mt. Pennell 15-minute quadrangle is 1,540 ft (469 m). The upper contact between the Blue Gate Shale and the overlying Emery Sandstone members is interfingering and gradational (Hunt, Averitt, and Miller, 1953).

The Emery Sandstone member of the Mancos Shale, like the Ferron Sandstone member, represents a period of marine regression and is the most important coal bearer in the quadrangle. It can be divided into three units.

The lowermost unit reflects littoral deposition and consists of gray to light brown, medium-grained, massive sandstone with thin interbeds of gray shale (Doelling, 1972, Hunt, Averitt, and Miller, 1953). The strata are even bedded to ripple laminated and typically form cliffs.

The middle unit is composed of yellowish-gray to brown, lenticular sandstone with shale partings. The upper unit contains gray shale, coal and some lenticular sandstone beds and is believed to be of nearshore fluvial origin. The average thickness of the Emery Sandstone member in the quadrangle is 185 ft (36 m).

The Emery Sandstone member is conformably overlain by the Masuk Shale member of the Mancos Shale. The Masuk Shale member occurs only on a small portion of Tarantula Mesa which is included in the map area. At this location, it consists of interbedded sandy gray shale, sandy carbonaceous shale and sandstone. The depositional environment for this member is

believed to have been a constantly shifting shoreline, a sand and mudflat that was subjected to repeated marine flooding. Beach deposits did not accumulate until near the end of the depositional period and are reflected by a gradual increase in littoral sandstone units which are transitional with the overlying Mesa Verde Formation (Hunt, Averitt, and Miller, 1953). The average thickness of the member in the map area is 800 ft (244 m).

Light tan, cliff-forming sandstones which cap Masuk Shale member atop Tarantula Mesa in the northwest corner of the map area are not coal bearing in the region.

Structure

The Northeast Quarter of the Mt. Pennell 15-minute quadrangle is on the east side of the Henry Mountains structural basin. Regional dips are gentle, in the range of 2 to 3 degrees, to the west.

The principal structural feature in the quadrangle is the dome generated by emplacement of the Mt. Pennell stock. Strata are inclined up to 80 degrees immediately adjacent to the stock. Dips decrease gradually away from Mt. Pennell until, in the southwest corner of the map area, bedding is nearly horizontal.

A series of faults has been mapped in a belt along the west margin of the quadrangle. The amount of displacement along the structures is not reported in available literature but, based upon their failure to offset formational contacts, is probably small.

Geologic History

Most pre-Cretaceous Mesozoic rocks in this part of the Colorado Plateau are continental in origin. Permian through the Jurassic continental deposition was along coastal plains adjacent to principal seaways. The major types of depositional environments that existed during this period were eolian, intertidal mudflats, lacustrine, fluvial and flood plains.

The Cretaceous history of the Henry Mountains coal field is similar to that of coal fields in central Utah and throughout the Colorado Plateau in general. The region is one in which classic transgressive and regressive sedimentation provided an environment for coal deposition.

During the early Cretaceous, the Henry Mountains region lay on a lowland plain over which neither subsidence nor uplift were occurring. However, sufficient erosion took place to remove lower Cretaceous strata and plane off the top of the Jurassic Morrison Formation.

Subsidence then resumed in the region and a sheet of fluvial sand and clay was deposited to form the Dakota Sandstone. Broad flood plains with swamps and lakes provided an environment in which vegetation flourished. Resulting accumulations of carbonaceous material formed local, thin coal seams in the region.

In the meantime, as subsidence increased, a sea in which the Mancos Shale was to be deposited began its encroachment from the east. The sea eventually covered all the Henry Mountains region

and extended westward to the present-day Wasatch Plateau area. The shoreline remained there throughout Mancos Shale deposition except for two dramatic regressions which deposited the Ferron and Emery Sandstone members. Orogenic pulses to the west supplied clastics for these sandstone members faster than the area could subside (Doelling, 1972). Marine shale deposition changed to nearshore sand and finally to lagoonal and fluvial sand and shale. Forests flourished, dead vegetation accumulated and, in places, coal was produced. All of the thick coal seams in the Henry Mountains Basin were deposited during these two events.

After deposition of the Mancos Shale the Cretaceous sea retreated permanently eastward. Although sedimentation undoubtedly continued in the Henry Mountains region, continental rather than marine beds were deposited and these were later removed by erosion.

According to Hunt and others (1953) the Waterpocket Fold and presumably the Henry Mountains structural basin were formed between the close of Cretaceous time and the Eocene epoch. Eocene deposits occur at places in the basin.

Emplacement of the Henry Mountains intrusives may have occurred anytime after early to mid-Tertiary. Thereafter the Colorado Plateau began its uplift and erosion instead of deposition dominated. This activity has continued to the present day.

COAL GEOLOGY

No surface coal sections have been measured in the Dakota Sandstone and Ferron Sandstone member of the Mancos Shale in the Northeast Quarter of the Mt. Pennell 15-minute quadrangle. Exposures of these formations occur on the flanks of Mt. Pennell, but the outcrops are poorly exposed.

The Ferron Sandstone member was penetrated by a single oil exploration drill hole in section 24, T. 33 S., R. 9 E. in the quadrangle. Six feet (1.8 m) of coal in several beds separated by one foot (30 cm) of rock were intersected at a depth of 1,398 ft (426 m). No other information on Ferron coal is available. The depth of its occurrence and typical non-economic condition elsewhere preclude it from resource consideration.

Coal in the Emery Sandstone member occurs in outcrops bordering Tarantula Mesa and Cave Flat along the west map margin. The coal zone in the Emery Sandstone member lies 140 ft (43 m) to 160 ft (49 m) above the base of the member and contains as many as five beds.

Thick, correlatable beds of Emery coal occur at several locations. The most notable is at the southeast corner of Tarantula Mesa. At a location in Section 1, T. 33 S., R. 9 E., the Em-3 coal bed maintains an average thickness of 7.1 ft (2 m) with .1 ft (3 cm) of rock partings over an outcrop length of 1,000 feet (304.8 m).

To the north along Tarantula Mesa, in sections 25 and 36, T. 32 S., R. 9 E., at least one of several coal beds (Em-2, Em-5) in the Emery coal zone maintains a minimum 5 ft (1.5 m) thickness over a strike length of 2,000 ft (610 m).

Southward, along the edge of Cave Flat in section 13, T. 33 S., R. 9 E., 5.1 to 9.7 ft (1.6 to 3.0 m) of coal in several beds separated by minor rock partings occupy the Emery coal zone. These beds are identified as Em-4 on the accompanying CRO maps.

Chemical Analyses of Emery Zone Coal

No analyses of coal samples from the quadrangle is available. However, Doelling (1972) reported the results of four Emery coal sample analyses for the adjacent Northwest Quarter of the Mt. Pennell 15-minute quadrangle (table 1). The analyses and on arithmetic average indicating a subbituminous A rank coal (ASTM, 1966) are shown in table 1.

Table 1 -- Average proximate analyses of coal samples in percent

	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb
1. Outcrop Emery Coal Bed Sec. 2, T.33S., R.9E.	10.48	42.30	49.99	6.33	0.83	11,468
2. Outcrop Emery Coal Bed Sec. 11, T.33S., R.9E.	11.34	40.65	49.40	9.27	0.49	10,856
3. Outcrop Emery Coal Bed Sec. 14, T.33S., R.9E.	12.29	41.02	50.91	5.96	0.59	11,147
4. Outcrop Emery Coal Bed Sec. 11, T.33S., R.9E.	13.70	42.01	49.89	5.30	0.51	11,121
Average Doelling (1972)	11.95	41.50	50.05	6.72	0.61	11,148

COAL RESOURCES

Data from one oil exploration drill hole and 34 measured surface sections and surface mapping by Doelling (1972) and Law (1979) were used to construct outcrop, isopach and structure contour maps of coal zones and beds in the quadrangle, (CRO plates 1 through 10).

Coal resources were calculated using data obtained from the coal isopach maps (CRO plates 4 and 8). The coal-bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed times a conversion factor of 1,770 short tons of coal per acre-foot for subbituminous coal yielded the coal resources in short tons of coal for each isopached coal bed. Reserve Base for the Em-2 through and Em-5 coal beds is shown on CRO plates 7 and 11, and is rounded to the nearest tenth of a million short tons. Only that coal equal to or thicker than the 5.0 ft (1.5 m) minimum advocated in U.S. Geological Survey Bulletin 1450-B is included in the Reserve Base. Thinner beds presently being mined or for which there is evidence that they could be mined commercially at this time are not included in the Reserve Base calculation. Coal Reserve Base for all coal beds thicker than 5.0 ft (1.5 m), as shown on CRO plate 2, totals about 8.57 million short tons. Reserve Base (in short tons) in the various development-potential categories for surface and underground mining methods are shown in tables 2 and 3.

Dames & Moore has not made any determination of economic recoverability for any of the coal beds described in this report.

Isolated Data Points

In instances where isolated measurements of coal beds of Reserve Base thickness or greater are encountered, the standard criteria for construction of isopach, structure contour, mining ratio and overburden isopach maps are not available. The lack of data concerning these coal beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known coal beds. For this reason, isolated data points are mapped separately. The isolated points mapped in this quadrangle are listed below and are shown on figures 2 and 3.

Source	Location	Coal Bed	Millions Short Tons	Thickness
LAW (1979)	Section 13 T.13S., R.9E.	Em-1	1.73	5.9 ft (1.8 m)
WEB RESOURCES FEDERAL CAVE FLAT #24	Section 24 T.33S., R.9E.	Fe-1	5.45	5.9 ft (1.8 m)

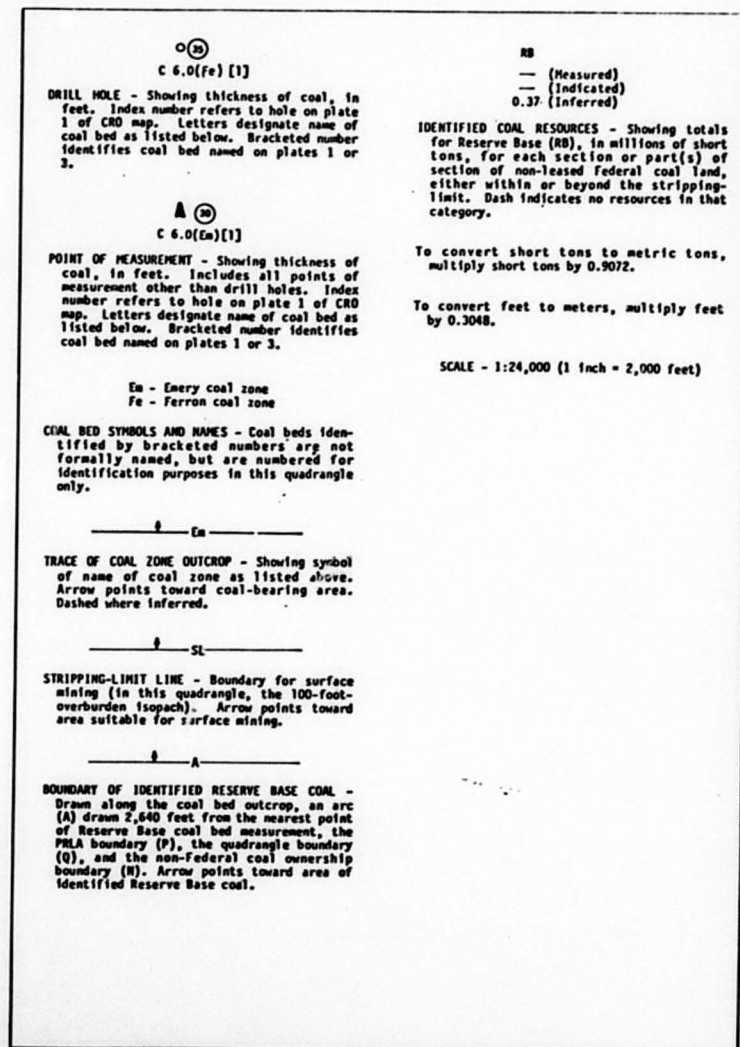


FIGURE 1. - Explanation for FIGURES 2 and 3.

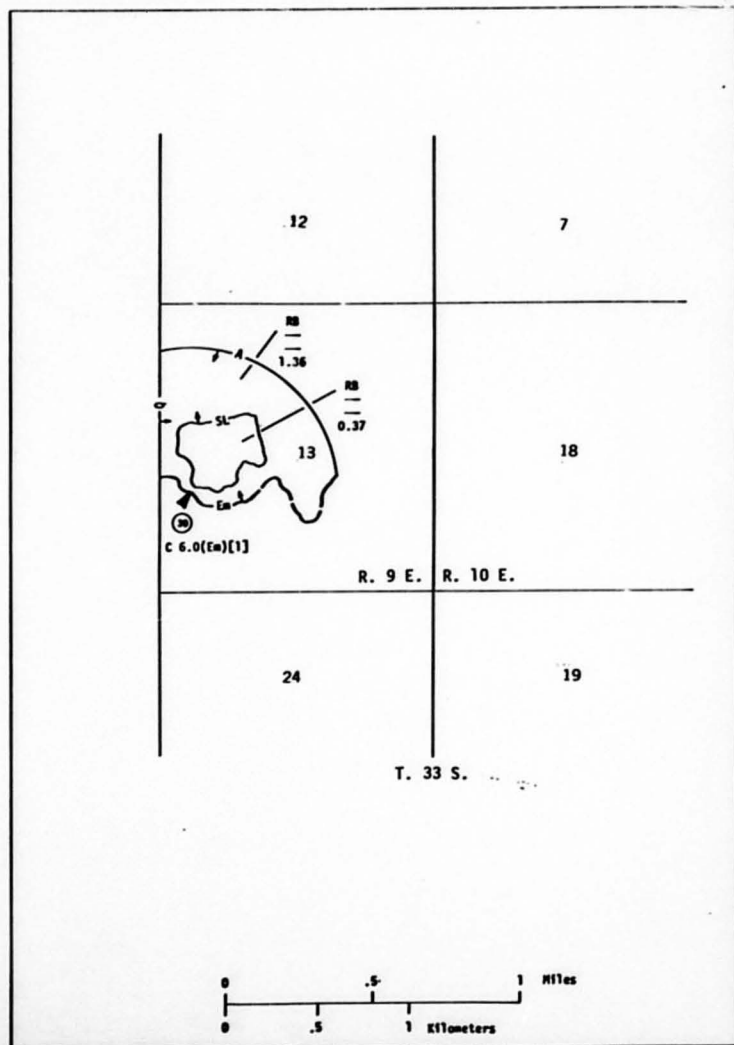


FIGURE 2. - Isolated data point map of the Emery [1] coal bed.

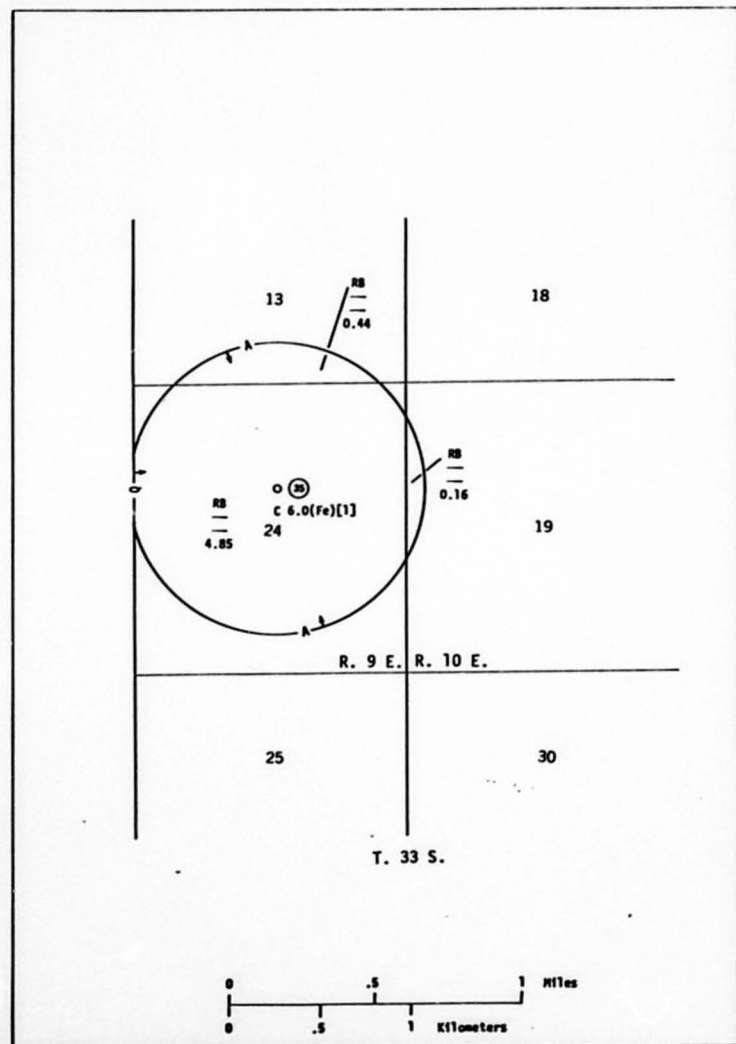


FIGURE 3. - Isolated data point map of the Ferron [1] coal bed.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn so as to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 100 ft (30 m) or less of overburden are considered to have development potential for surface mining and were assigned a high, moderate or low development potential based upon the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios is as follows:

$$MR = \frac{t_o}{t_c} (cf)$$

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short ton of recoverable coal:

0.911 for subbituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. These mining-ratio values for each development-potential category are based on economic and technological criteria; they are applicable only to this quadrangle and were derived in consultation with J. Moffit, Area Mining Supervisor, U.S. Geological Survey.

Areas where the coal data are absent or extremely limited between the 100-foot (30 m) overburden line and the outcrop are assigned unknown development potential for surface mining methods. This applies to those areas where no known coal beds 5 feet (1.5 m) or more thick occur or where coal exceeds 5 feet (1.5 m) but data is insufficient to properly evaluate coal

development potential. Limited knowledge pertaining to the areal distribution, thickness, depth and attitude of the coal beds prevents accurate evaluation of the development potential in the high, moderate or low categories.

The coal development potential for surface mining methods is shown on plate 12. Of the Federal land areas assigned a development potential for surface mining methods, 33.3 percent are rated high, 10.3 percent moderate, 2.3 percent low and 54 percent unknown. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where the coal beds of Reserve Base thickness are between 100 and 3,000 feet (30 and 914 m) below the ground surface and have dips of 15° or less. Coal beds lying between 100 and 3,000 feet (30 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Areas of high, moderate and low development potential for subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 100 to 1,000 feet (30 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m), respectively.

Areas where the coal data are absent or extremely limited between 100 and 3,000 feet (30 and 914 m) below the ground surface are assigned unknown development potentials. Even though these areas may contain coal thicker than 5 feet (1.5 m), limited knowledge pertaining to the areal distribution, thickness, depth and attitude of the coal beds prevents accurate evaluation of the development potential in the high, moderate or low categories.

The coal development potential for subsurface mining methods is shown on plate 13. Of the Federal land areas assigned a development potential for conventional subsurface mining methods, 4 percent are assigned a high development potential and 96 percent are assigned an unknown development potential. The remaining Federal land is classified as having unknown development potential for conventional subsurface mining methods.

Table 2 -- Coal Reserve Base Data for surface mining methods for Federal coal lands (in short tons) in the Northeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah

[Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/t , multiply by 0.842]

Coal bed (0-10 mining ratio)	High development potential (10 - 15 mining ratio)	Moderate development potential (>15 mining ratio)	Low development potential	Unknown development potential	Total
Em-1	---	---	---	1,360,000	1,360,000
Em-2	10,000	---	---	---	10,000
Em-3	630,000	120,000	20,000	---	770,000
Em-4	160,000	90,000	10,000	---	260,000
Em-5	40,000	50,000	30,000	---	120,000
Fe-1	---	---	---	---	---
Total	840,000	260,000	60,000	1,360,000	2,520,000

Table 3 -- Coal Reserve Base Data for subsurface mining methods for Federal coal lands (in short tons) in the Northeast Quarter of the Mt. Pennell 15-minute quadrangle, Garfield County, Utah.

[To convert short tons to metric tons, multiply by 0.9072]

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Em-1	---	---	---	370,000	370,000
Em-2	---	---	---	---	---
Em-3	---	---	---	---	---
Em-4	210,000	---	---	---	210,000
Em-5	20,000	---	---	---	20,000
Fe-1	---	---	---	5,450,000	5,450,000
Total	230,000	---	---	5,820,000	6,050,000

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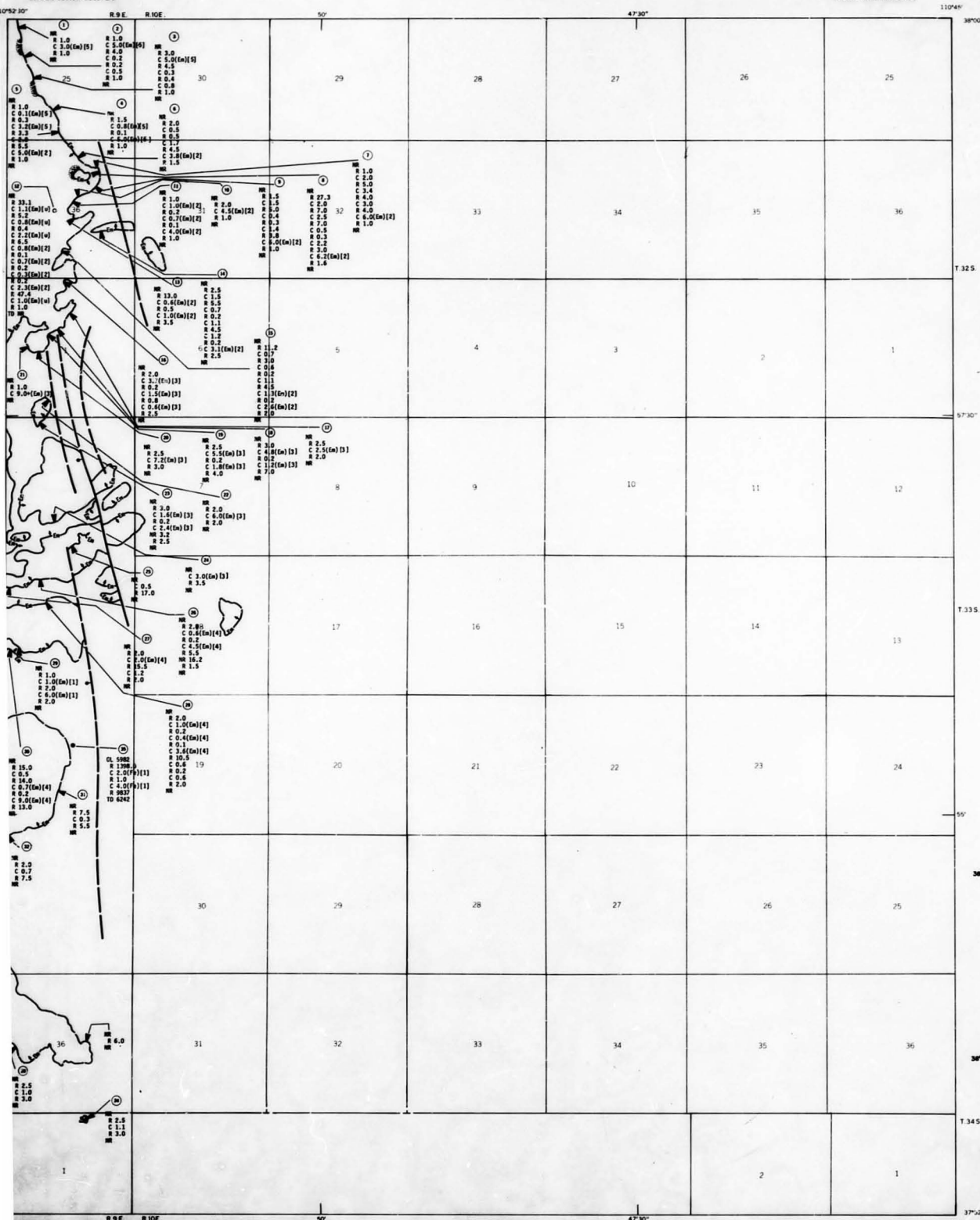
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EXPLANATION

GL 5980
R 1398.0
C 2.0(m)[1]
R 1.0
C 2.0(m)[1]
R 0.007
TO 6242

DRILL HOLE - Shows solid for oil and gas open for coal. Drill-hole data are given in feet. Index number refers to hole plate of CDS map or in table of test. Bracketed number(s) designate name of coal bed(s) listed below. Unidentified coal bed in outcrop sections are not followed coal bed numbers.

GL - Ground level
NR - No record
R - Rock interval
C - Coal interval
TD - Total depth

OUTCROP MEASURED SECTION - Showing rock interval and coal thicknesses, in feet. Index number refers to section on plate of CDS map or in table of test. Bracketed number(s) designate name of coal bed(s) listed below. Unidentified coal bed in outcrop sections are not followed coal bed numbers.

TEST HOLE AND MEASURED SECTION DATA SYMBOL:
En - Entry coal zone
En(u) - Entry coal zone, undifferentiated
Fe - Ferron coal zone

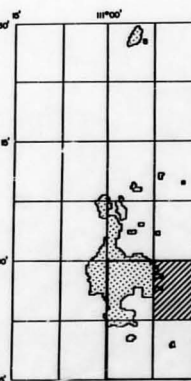
COAL BED SYMBOLS AND MAPS - Coal bed identified by bracketed numbers are a formally named, but are numbered for identification purposes in this quadrangle only.

TRACE OF COAL ZONE OUTCROP - Letters designate name of coal zone as listed above. Arrow points toward coal-bearing area. Dashed line indicates inferred outcrop.

BURNED AND CLIMBED COAL - Showing area of burned and fused rock (x symbol). Dotted line indicates the inferred limit of burning.

TRACE OF FAULT - Bar and half on down throw side. Dashed where inferred or approximately located.

To convert feet to meters, multiply feet by 0.3048.



MAP SHOWING LOCATION OF THE NE 1/4 OF THE MT. PENNELL 15-MINUTE QUADRANGLE (HATCHED) AND THE MOUNTAIN KNOWN RECOVERABLE COAL RESOURCE AREA (STIPPLED), UTAH.

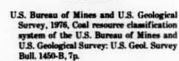
From U.S. Geological Survey, 1953

This report has not been edited
conformity with U.S. Geological
Survey editorial standards or
geographic nomenclature.

**COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES AND MOORE
1979**



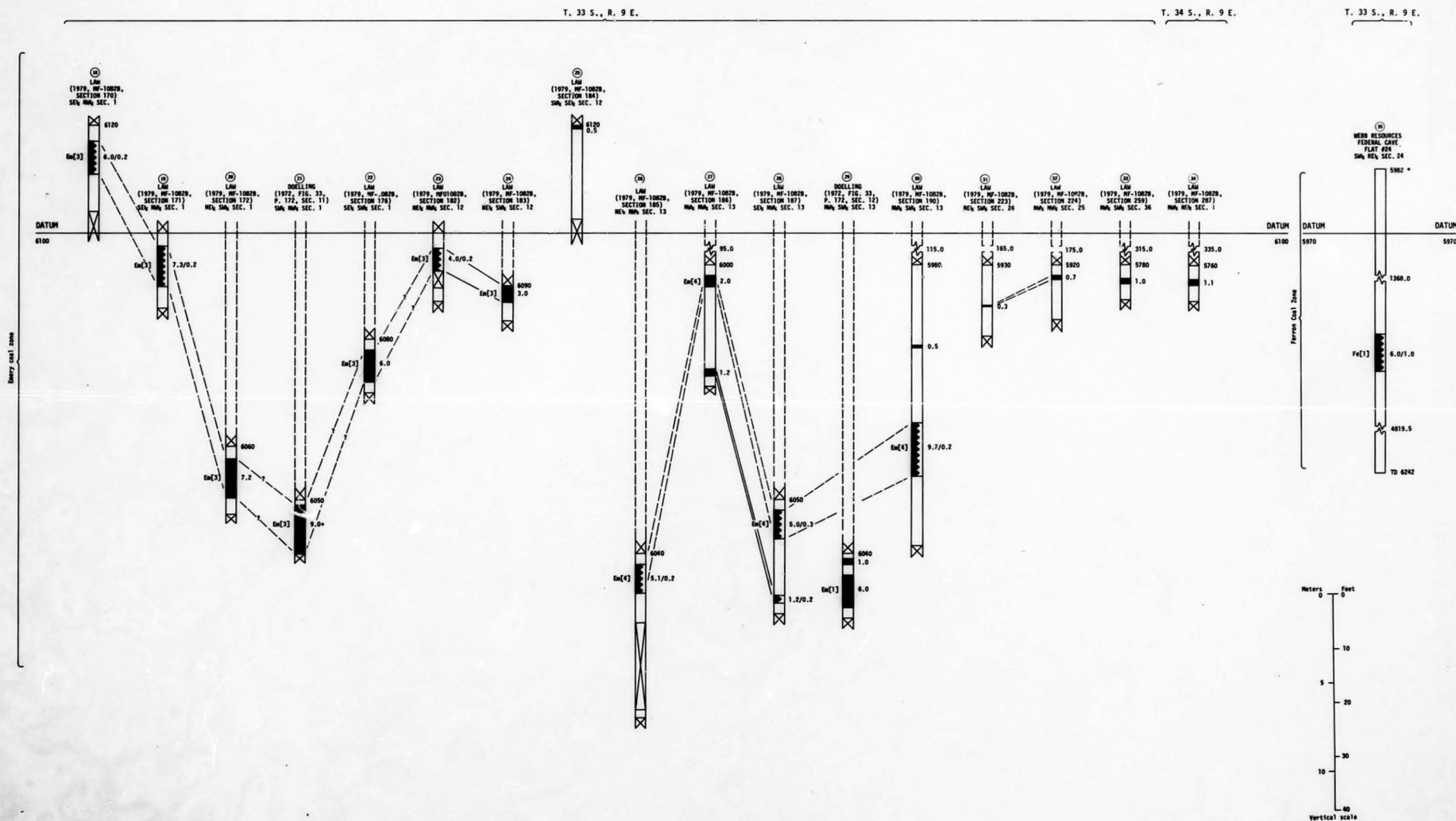
PLATE 1
COAL DATA MAP



Compiled in 1978/79

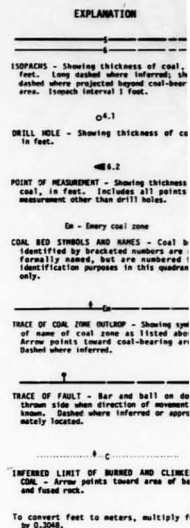
PLATE 2
BOUNDARY AND COAL
DATA MAP

CORRELATION OF COAL BEDS IN DRILL HOLES AND MEASURED SECTIONS



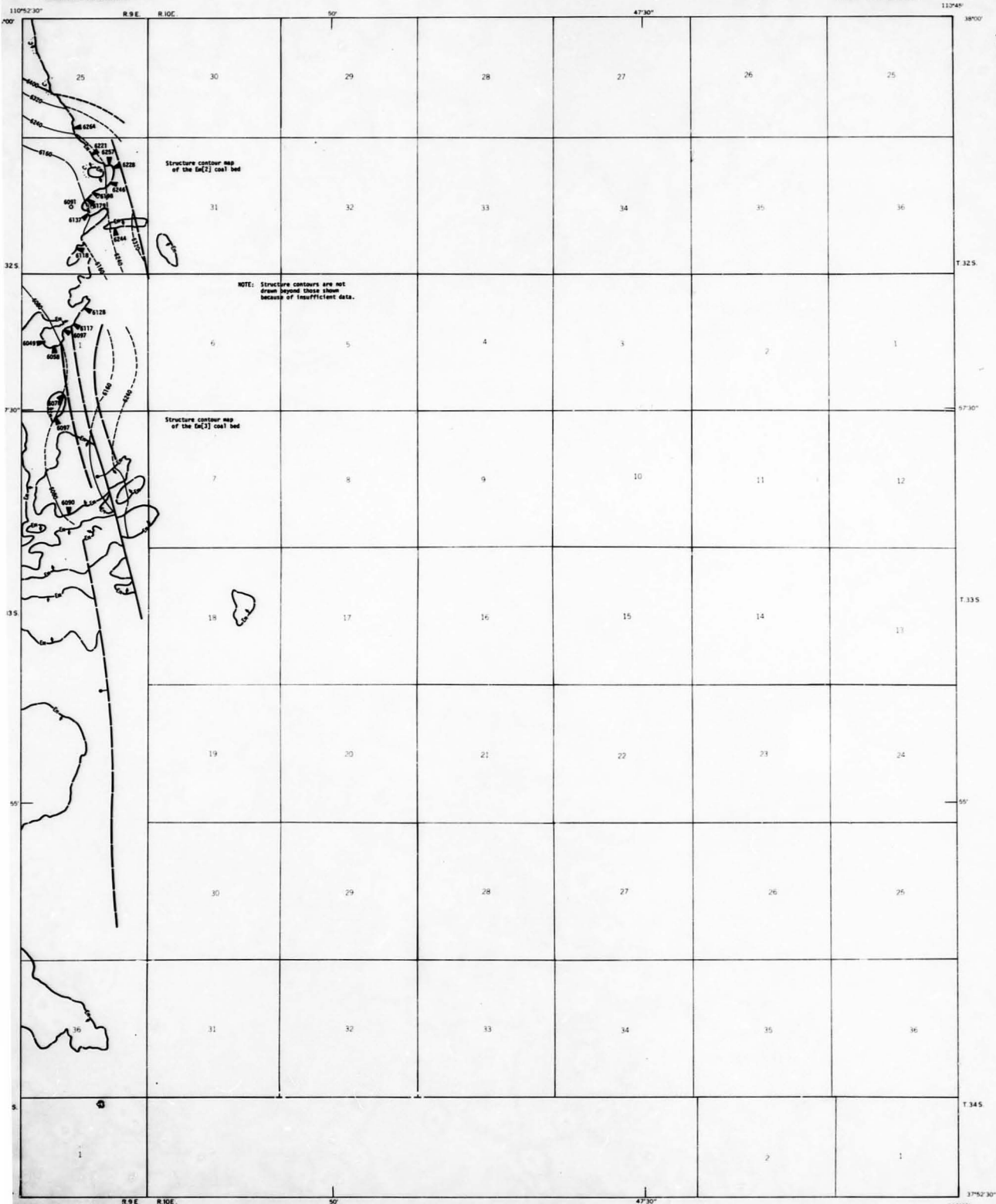
COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE MT. PENNELL
15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES & MOORE

THIS REPORT HAS NOT BEEN EDITED
FOR TECHNICAL CONTENT BY THE
SURVEY EDITORIAL STANDARDS OR
STRATIGRAPHIC NOMENCLATURE.



Compiled in 1978/79

PLATE 4
ISOPACH MAPS OF THE
EMERY [2] AND EMERY [3] COALS



EXPLANATION

— 6200
— 6220

STRUCTURE CONTOURS - Drawn on top of bed. Solid where vertical accuracy is within 80 feet; long dashed where accuracy possibly not within 80 feet; dashed where projected above ground face. Contour interval 80 feet. Datum is mean sea level.

○ 6091
DRILL HOLE - Showing altitude of top bed, in feet.

— 6254
POINT OF MEASUREMENT - Showing altitude of top of coal bed, in feet. Includes points of measurement other than holes.

Em - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers; formally named, but are number identification purposes in this map only.

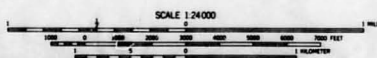
— 6254
TRACE OF COAL ZONE OUTCROP - Showing of name of coal zone as listed. Arrow points toward coal-bearing bed where inferred.

— 6254
TRACE OF FAULT - Bar and ball of throw side when direction of movement known. Dashed where inferred or not locally located.

— 6254
INFERRED LIMIT OF BURNED AND CL COAL - Arrow points toward area of and fused rock.

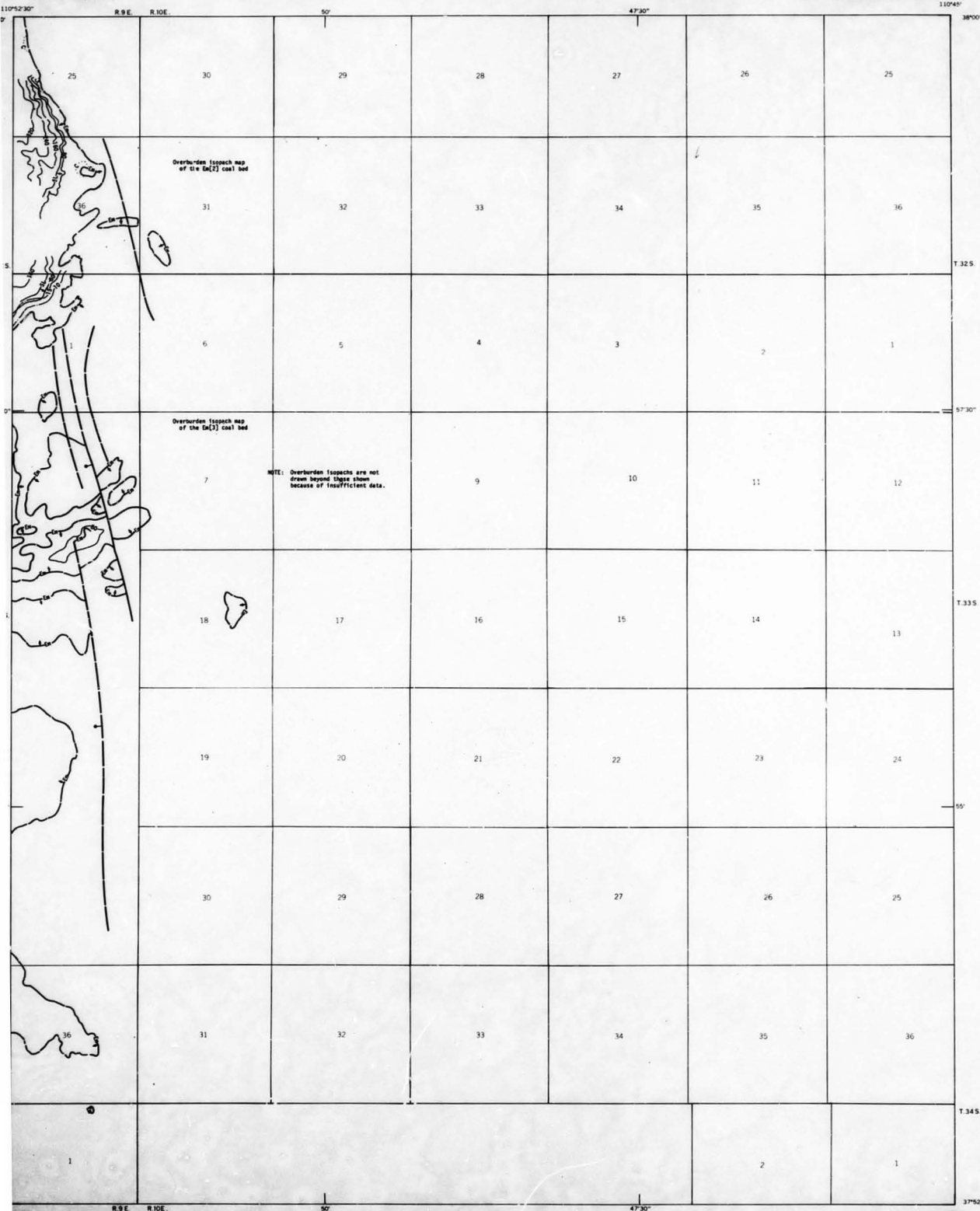
To convert feet to meters, multiply by 0.3048.

Base from U.S. Geological Survey, 1953
This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.



Compiled in 1978/79

**COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES AND MOORE
1979**



EXPLANATION

OVERBURDEN ISOPACHS - Showing thickness of overburden, in feet, from surface to top of coal bed. Isopach interval 20 (24 ft).

STRIPPING-LIMIT LINE - Boundary for an area in which stripping is planned. In this quadrangle, the 100-foot overburden (isopach). Arrow points to stripping area.

MIXING-RATIO CONTOUR - Number indicates cubic yards of overburden per ton of recoverable coal by surface mining method. Contours shown only in areas underlain by coal of average base thickness within stripping-limit. To convert mining to cubic meters of overburden per ton of recoverable coal, multiply ratio by 0.8426.

Em - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers are formally named, but are numbered for identification purposes in this quadrangle only.

TRACE OF COAL ZONE OUTCROP - Showing a of name of coal zone as listed at Arrow points toward coal-bearing. Dashed where inferred.

INFERRED LIMIT OF MINED AND CLIM COAL - Arrow points toward area of and fused rock.

TRACE OF FAULT - Bar and ball on a through side when direction of movement known. Dashed where inferred or apparently located.

To convert feet to meters, multiply by 0.3048.

U.S. Geological Survey, 1953

This report has not been edited for conformity with U.S. Geological Survey editorial standards or cartographic nomenclature.

Compiled in 1976/79

COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH

BY
DAMES AND MOORE
1979

PLATE 6

OVERBURDEN ISOPACH AND
MINING RATIO MAPS OF THE
EMERY M AND EMERY C COAL

EXPLANATION

NON-FEDERAL COAL LAND - Land for which Federal Government does not own rights.

ISOPACH - Showing thickness of coal bed in feet. Arrow points toward area where bed is 5 feet or more thick.

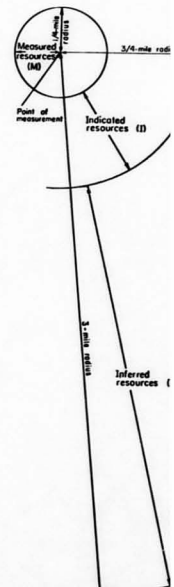
EM - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers. Formally named, but are number identification purposes in this case only.

TRACE OF COAL ZONE OUTCROP - Showing of name of coal zone as listed. Arrow points toward coal-bearing. Dashed where inferred.

RB R(BSS)
0.50 0.51 (Measured)
— — (Inferred)

IDENTIFIED COAL RESOURCES - Showing for Reserve Base (RB) and Reserves (R) of short tons, for each section of non-leased Federal land, both within and beyond the st. limit line. Reserve (R) tonnage is listed by multiplying the Reserve R. tonnage by the appropriate recovery factor. Reserves have been calculated constant thickness of 12 feet to where the coal beds are more than thick. Therefore, in some cases underground reserves may be less percent of the Reserve Base.



BOUNDARY LINES - enclosing areas of measured (M), indicated (I), and inferred (F) resources.

To convert short tons to metric multiply short tons by 0.9072.

To convert feet to meters, multiply by 0.3048.

To convert miles to kilometers, multiply by 1.6093.

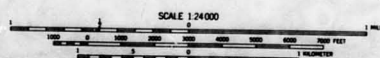
PLATE 7

AREAL DISTRIBUTION AND IDENTIFIED RESOURCES MAPS OF EMERY AND EMERY COAL

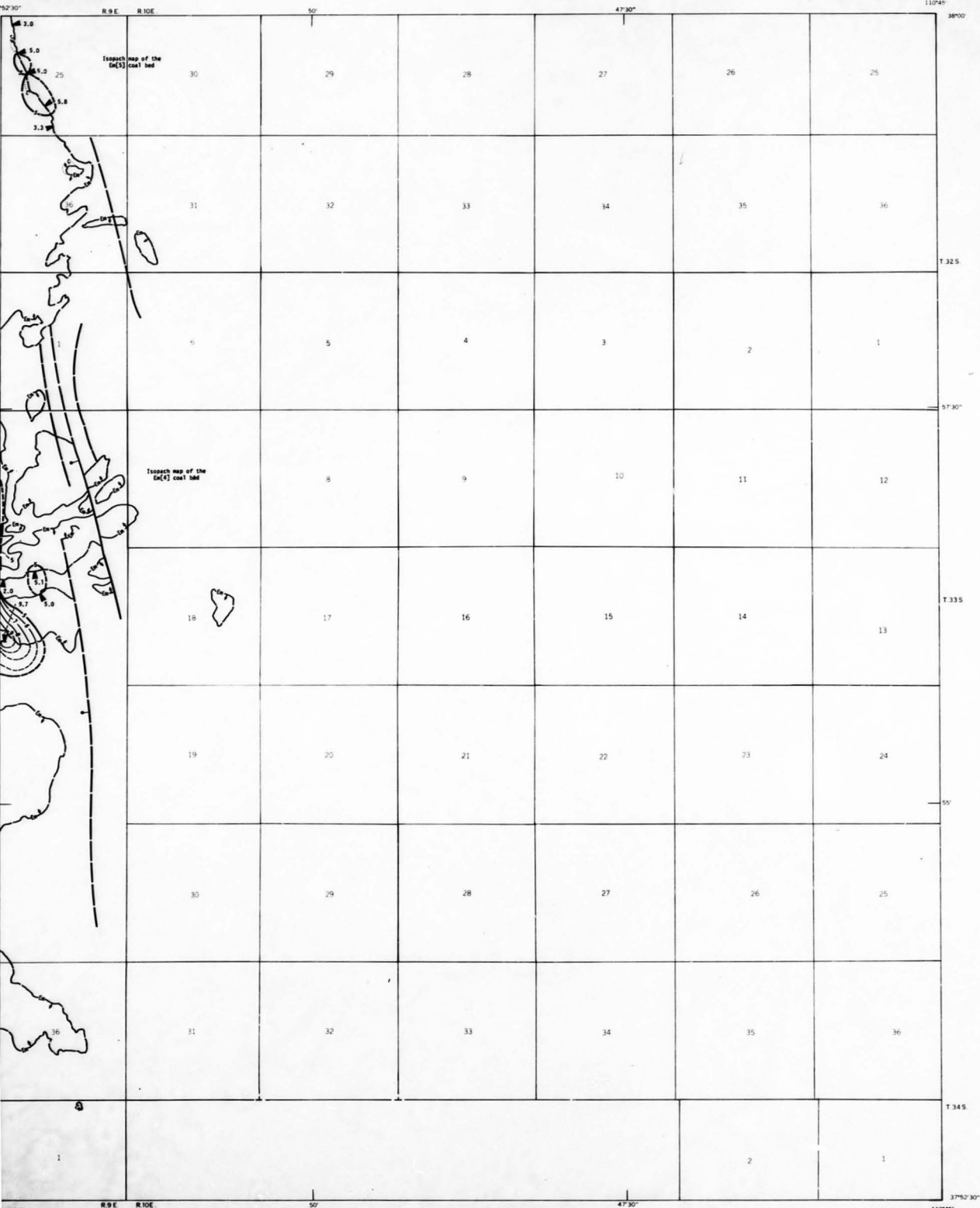
COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES AND MOORE
1979

Base from U.S. Geological Survey, 1953

This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.



Compiled in 1976/79



EXPLANATION

ISOPACHS - Showing thickness of coal feet. Long dashed where inferred; dashed where projected beyond coal-bed area. Isopach interval 1 foot.

POINT OF MEASUREMENT - Showing thickness coal, in feet. Includes all point measurement other than drill holes.

Em - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers are formally named, but are numbered identification purposes in this quadrangle only.

TRACE OF COAL ZONE BOUNDARY - Showing by of name of coal zone as listed above. Arrow points toward coal-bearing a dashed where inferred.

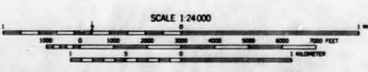
TRACE OF FAULT - Bar and ball on a chosen side. Dashed where inferred approximately located.

INFERRED LIMIT OF BURNED AND CLINE COAL - Arrow points toward area of 1 and fused rock.

To convert feet to meters, multiply by 0.3048.

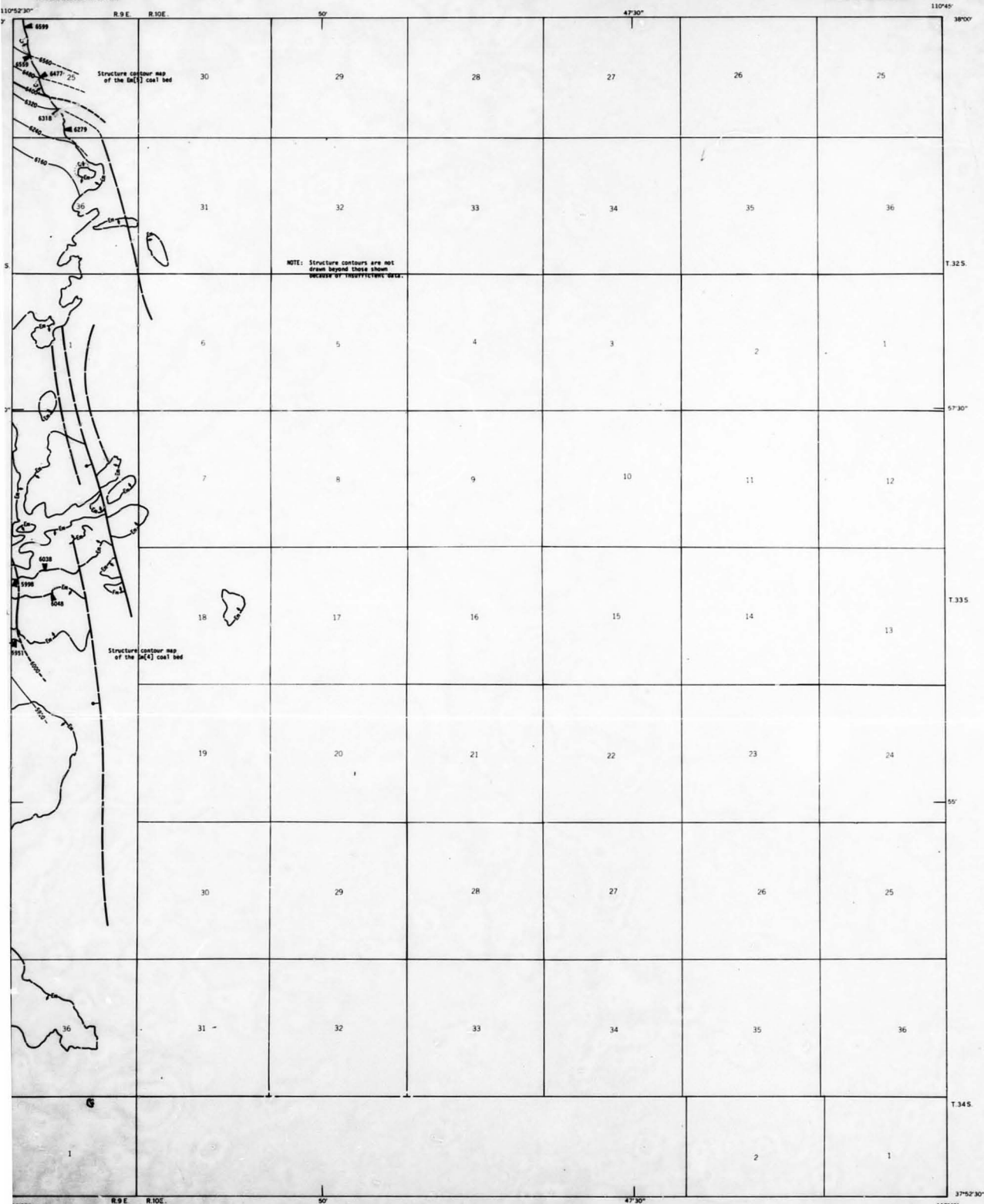
See from U.S. Geological Survey, 1957

This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.



Compiled in 1978/79

**COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES AND MOORE
1979**



EXPLANATION

STRUCTURE CONTOURS - Drawn on top of bed. Solid where vertical accuracy within 80 feet; long dashed where vertical accuracy possibly not within 80 feet; dashed where projected above ground face. Contour interval 80 feet (24 datum is mean sea level).

POINT OF MEASUREMENT - Showing alt. of top of coal bed, in feet. Include points of measurement other than holes.

Em - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers are formally named, but are numbered for identification purposes in this quadrangle only.

TRACE OF COAL ZONE OUTCROP - Showing name of coal zone as listed at Arrow points toward coal-bearing area. Dashed where inferred.

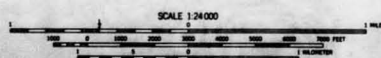
TRACE OF FAULT - Bar and ball on thrown side. Dashed where inferred approximately located.

INFERRED LIMIT OF BURNED AND CLINK COAL - Arrow points toward area of burned and fused rock.

To convert feet to meters, multiply by 0.3048.

See First U.S. Geological Survey, 1953

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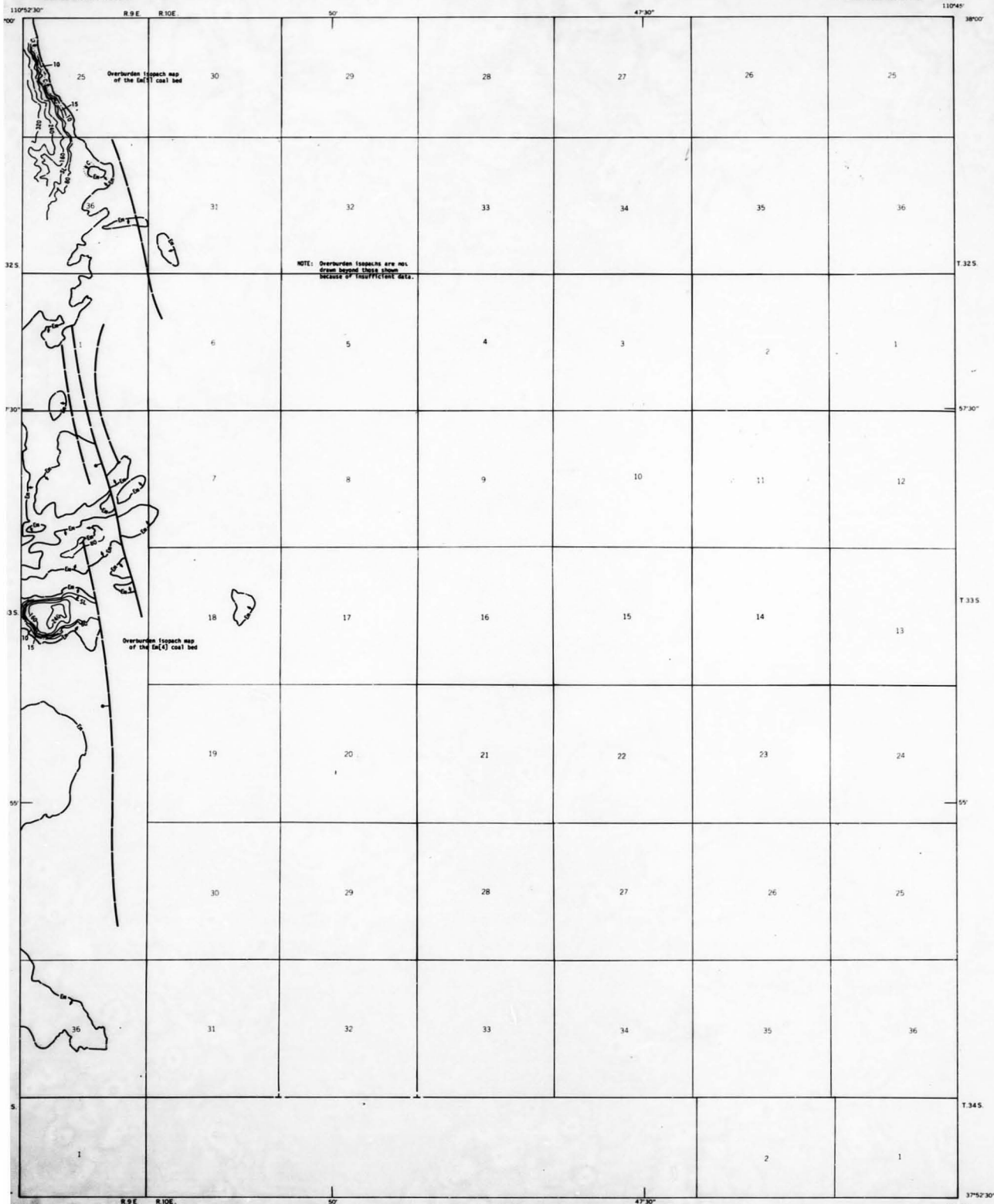


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MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH**

**BY
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1979**

**PLATE 9
STRUCTURE CONTOUR MAPS OF
EMERY [A] AND EMERY [B] COAL BEDS**



EXPLANATION

OVERBURDEN ISOPACHS - Showing thick overburden, in feet, from surface to coal bed. Dashed where vertical is possibly not within 40 feet. Interval 40 feet (20 m).

STRIPPING-LIMIT LINE - Boundary for mining (in this quadrangle, the 10 overburden isopach). Arrow points stripable area.

MINING-RATIO CONTOUR - Number in cubic yards of overburden per recoverable coal by surface mining. Contours shown only in areas under coal of recoverable thickness with stripping-limit. To convert mining to cubic meters of overburden per ton of recoverable coal, multiply ratio by 0.8428.

Em - Emery coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers, formally named, but are number identification purposes in this case only.

TRACE OF COAL ZONE OUTCROP - Showing of some of coal zone as listed. Arrow points toward coal-bearing. Dashed where inferred.

INFERRED LIMIT OF MINED AND CL. COAL - Arrow points toward area of and fused rock.

TRACE OF FAULT - Bar and ball on throw side when direction of move known. Dashed where inferred or a merely located.

To convert feet to meters, multiply by 0.3048.

Base from U.S. Geological Survey, 1953

This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

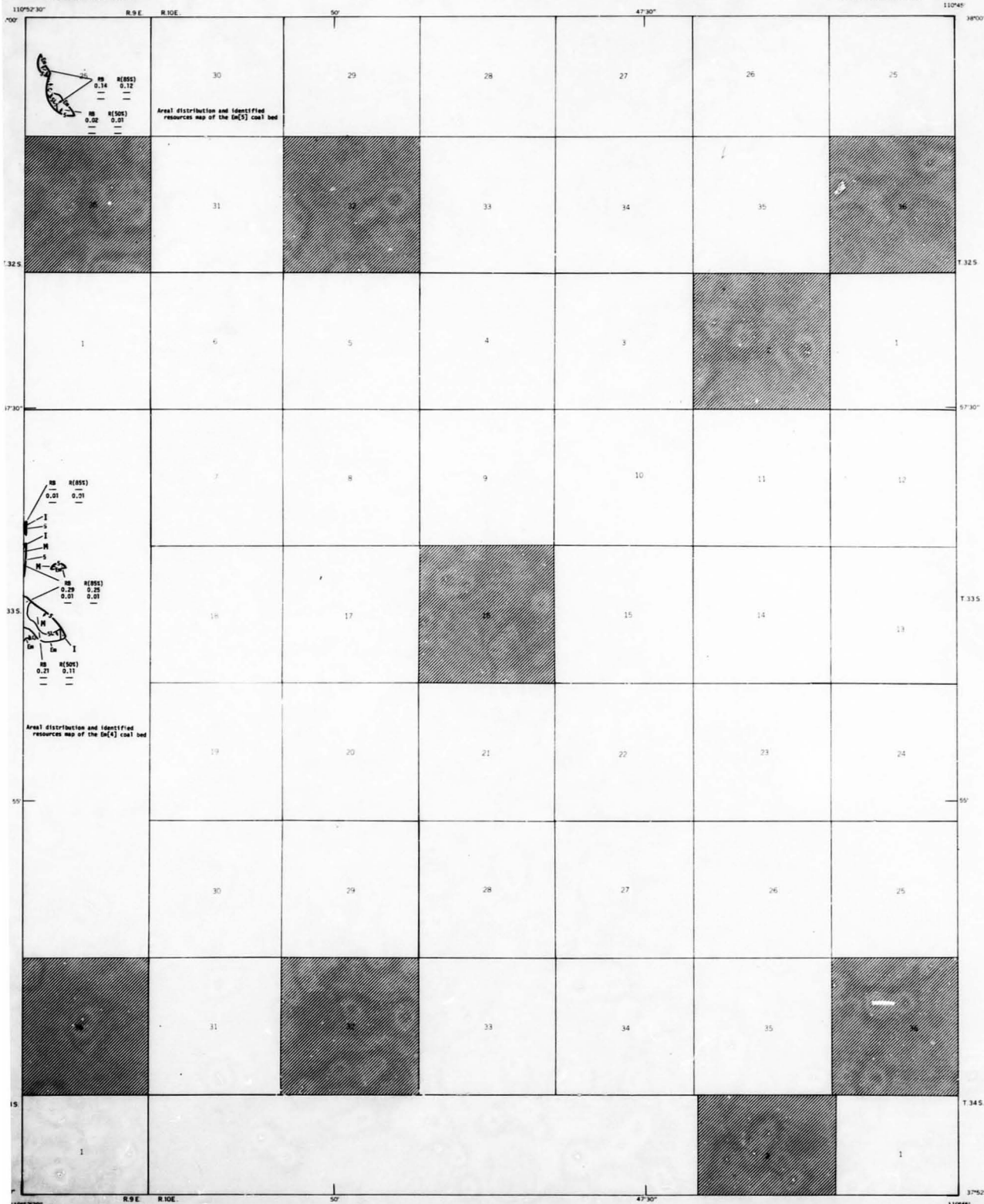


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**COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH**

**BY
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1979**

**PLATE 10
OVERBURDEN ISOPACH &
MINING RATIO MAPS OF
EMERY EM AND EMERY EM CO**



EXPLANATION

NON-FEDERAL COAL LAND - Land for which Federal Government does not have rights.

ISOPACH - Showing thickness of coal in feet. Arrow points toward area where coal is 5 feet or more thick.

Co - Every coal zone

COAL BED SYMBOLS AND NAMES - Coal identified by bracketed numbers formerly named, but are numbers identification purposes in this map only.

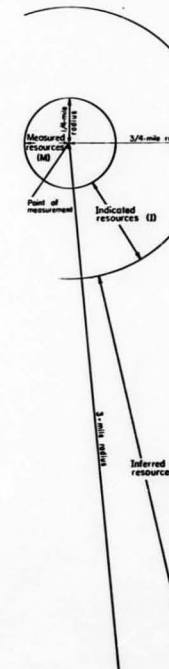
TRACE OF COAL ZONE OUTCROP - Showing of name of coal zone as listed. Arrow points toward coal-bearing. Dashed where inferred.

INFERRED LIMIT OF BURNED AND CL COAL - Arrow points toward area of land rock.

STRIPPING-LIMIT LINE - Boundary for mining in this quadrangle, the 1000-foot line. Arrow points the area suitable for surface mining. The recovery factor is 85 percent. From the area suitable for subsurface mining (down dip to the 3,000-foot line) where the recovery factor percent.

RB	R(BSS)	RB	R(SOS)	RB	R(SOS)
0.29	0.29	0.21	0.11	0.29	0.29
0.01	0.01	0.01	0.01	0.01	0.01

IDENTIFIED COAL RESOURCES - Showing for Reserve Base (RB) and Reserves (R) of short tons, for each 1/4 section of section of non-landed coal land, both within and beyond the 1000-foot line. Reserve (R) is indicated by multiplying the Reserve B (base) by the appropriate recovery factor. Dashed indicates no resource in this area. Reserves have been calculated constant thickness of 12 feet (1) where the coal beds are more than 12 feet thick. Therefore, in some (1) underground Reserves may be less percent of the Reserve Base.



BOUNDARY LINES - Enclosing areas of a (M), indicated (I), and inferred (R) resources.

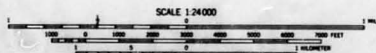
To convert short tons to metric multiply short tons by 0.9072.

To convert feet to meters, multiply by 0.3048.

To convert miles to kilometers, multiply by 1.6093.

Base from U.S. Geological Survey, 1953

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Compiled in 1976/79


COAL RESOURCE OCCURRENCE MAP OF THE NORTHEAST QUARTER OF THE MT. PENNELL 15-MINUTE QUADRANGLE, GARFIELD COUNTY, UTAH


BY
DAMES AND MOORE
1979

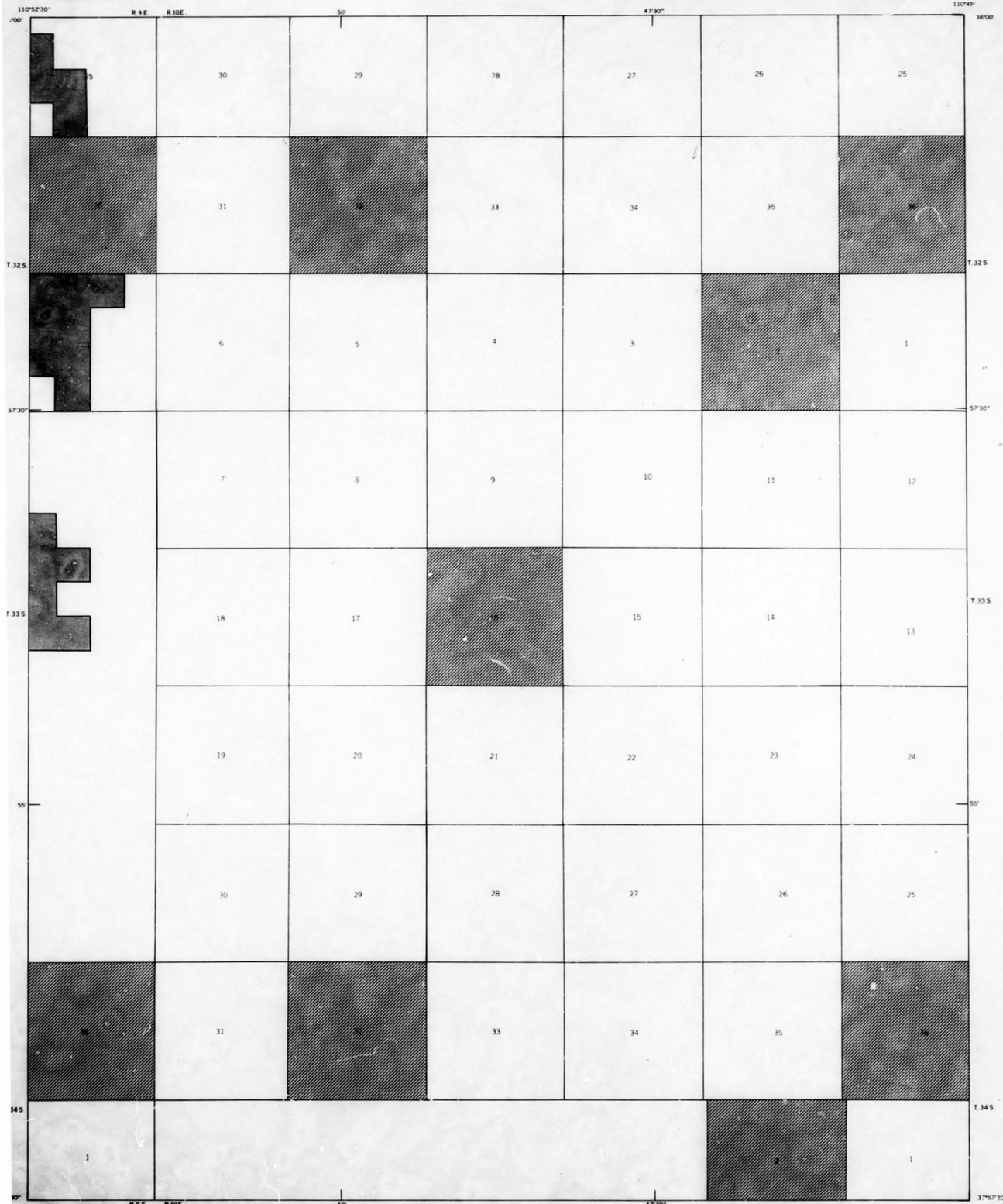
PLATE 11
AREAL DISTRIBUTION AND IDENTIFIED COAL RESOURCES MAPS OF THE NE 1/4 MT PENNELL 15' QUADRANGLE, GARFIELD COUNTY, UTAH

EXPLANATION

 NON-FEDERAL COAL LAND - Land for Federal Government does not own rights, and for which the coal-o potential is not rated.

 AREA OF HIGH COAL-DEVELOPMENT P
Area has mining-ratio values rang to 10.

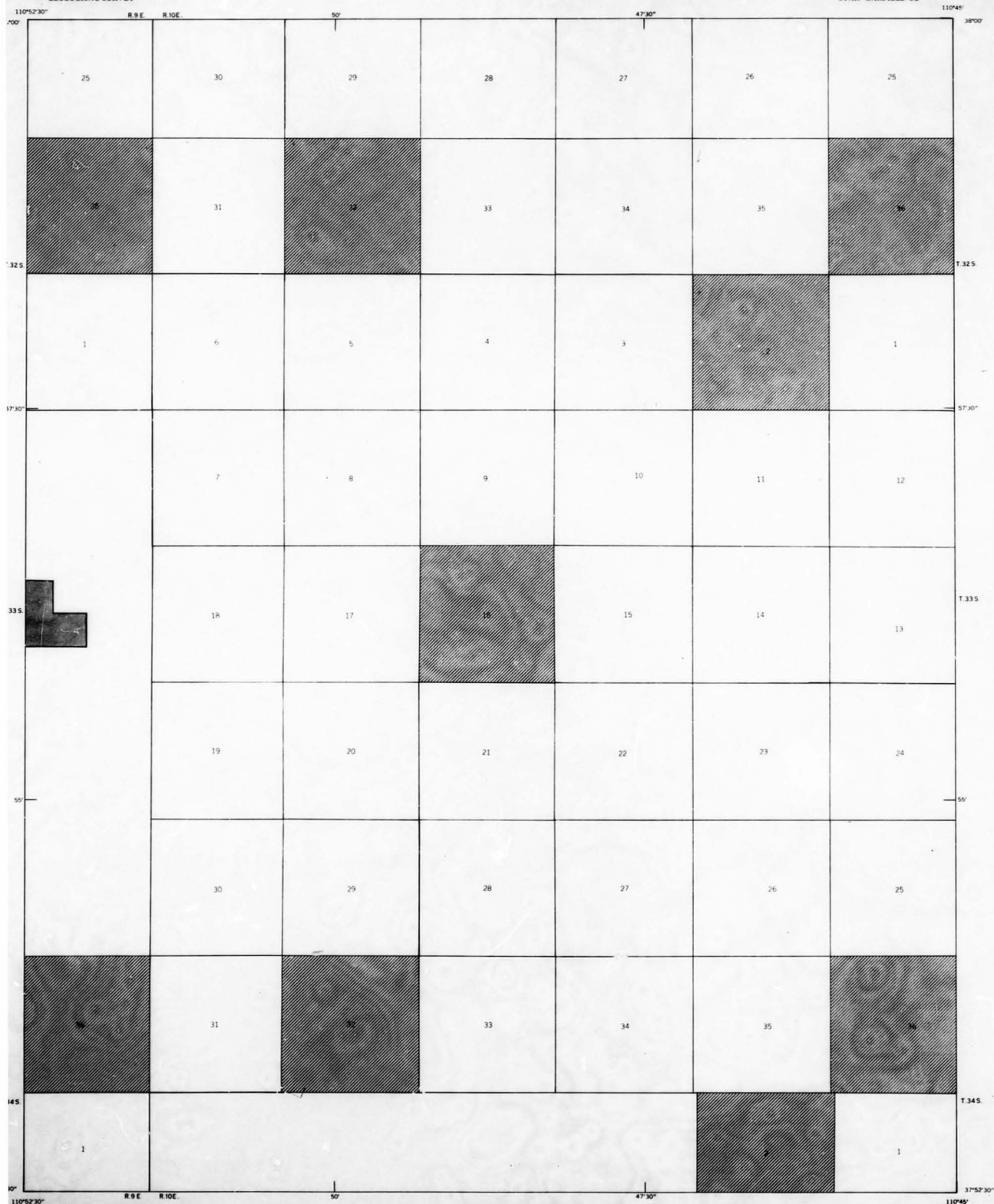
 AREA OF UNKNOWN COAL-DEVELOPMENT P
Area contains no known coal : feet (1.5 m) or more thick w feet (61 m) of the surface, bearing units are present in



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Survey editorial standards or
cartographic nomenclature.

**COAL DEVELOPMENT POTENTIAL MAP OF THE NORTHEAST QUARTER OF THE
MT. PENNELL QUADRANGLE, GARFIELD COUNTY, UTAH
BY
DAMES AND MOORE
1978**

PLATE 12
COAL DEVELOPMENT POTENTIAL
FOR SURFACE MINING



EXPLANATION

NON-FEDERAL COAL LAND - Land for which Federal Government does not own rights, and for which the coal-development potential is not rated.

AREA OF HIGH COAL-DEVELOPMENT POTENTIAL - Area containing coal in beds 5 feet or more thick between the strip-sill line (in this quadrangle, the 10 overburden isopach) and a depth of feet (300 m).

AREA OF UNKNOWN COAL-DEVELOPMENT POTENTIAL - Area containing no known coal in bed (2.5 m) or more thick, but coal units are present in area at depth than 3,000 feet (914 m).

Base from U.S. Geological Survey, 1983

Compiled in 1978-79

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COAL DEVELOPMENT POTENTIAL MAP OF THE NORTHEAST QUARTER OF THE MT. PENNELL QUADRANGLE, GARFIELD COUNTY, UTAH

BY
DAMES AND MOORE
1979

PLATE 13
COAL DEVELOPMENT POTENTIAL
FOR SUBSURFACE MINING